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Response of Inbred Corn Lines to Drouth Under Several Different Environmental Conditions

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RESPONSE OF INBRED CORN LINES TO DROUTH UNDER SEVERAL DIFFERENT ENVIRONMENTAL CONDITIONS

BY

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ENVIRONMENTAL CONDITIONS

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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P.T.N.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

Table		Page
XXVI.	ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS IN A GREENHOUSE	35
XXVII.	MEAN APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE	35
XXVIII.	ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE	36
XXIX.	MEAN LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS IN THE GREENHOUSE	38
XXX.	ANALYSIS OF VARIANCE FOR LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS IN THE GREENHOUSE . . .	38
XXXI.	MEAN LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE	39
XXXII.	ANALYSIS OF VARIANCE FOR LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE	39
XXXIII.	PLANTS FAILING TO SURVIVE FOLLOWING WATERING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS DRIED OUTSIDE	41
XXXIV.	ANALYSIS OF VARIANCE FOR PLANTS FAILING TO RECOVER FROM DROUTH TREATMENT IN FLATS OUTSIDE	41
XXXV.	CORRELATION COEFFICIENTS BETWEEN APPEARANCE, LEAF ROLLING, AND SURVIVAL OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS	42
XXXVI.	CORRELATION COEFFICIENTS OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIELD, IN A GREENHOUSE BENCH, AND IN FLATS	45

LIST OF FIGURES

INTRODUCTION

Recorded in the pages of history are many tragic tales based on man's want of more food. Many of these cases were brought about by drouth conditions and the crop destruction which followed. Man in his quest for protection from such catastrophies has observed that some plants seem able to withstand the drouth conditions that kill or severely damage others. With this information at hand, he has tried to find the reason why this is true, and to find ways to more fully utilize this tolerance to his own advantage. The agent or agents responsible for this tolerance have never been specifically pinpointed; however, certain internal and external conditions of the plants often seem to be correlated with it. The problem is complicated by the fact that the conditions correlated with resistance in one species may be completely different from those in another. An example of this difference is the correlation of osmotic pressure of plant juices with drouth resistance. Bartel (1), using four varieties of wheat, found the osmotic pressure increase during periods of drouth paralleled accepted differences in drouth resistance. On the other hand Schmidt, et al. (14) found the most drouth resistant variety of sugar beet had one of the lowest osmotic values. In other species there are no known characteristics that differ, yet there are distinct differences in drouth resistance.

Since natural conditions are often too erratic for accurate studies of drouth, it would be very desirable to find a simple technique for selecting plants or varieties under controlled conditions. The method would be even more desirable if seedling reactions could be correlated with mature plant responses so that large numbers of plants could be tested in a short period of time.

This investigation was conducted in an attempt to develop such a technique for evaluating the potential drouth resistance of corn germ plasm. Forty inbred lines of corn were subjected to various drouth conditions in the field, and in the greenhouse. The results obtained were then analyzed to determine whether responses under greenhouse conditions corresponded to those found in the field.

REVIEW OF LITERATURE

Because of limited equipment and technical knowledge many of the rly experiments were rather crude. Refinement of the experimental thod has greatly increased the scope and precision of many experi- nts. Although many advances have been made, the mystery still remains to what is the basis for drouth tolerance.

Until 1912, much of the drouth resistance of plants was attri- ted to the inherent differences in capacity to absorb moisture ilable in the soil. The experiments of Briggs and Schantz (2) showed at the wilting coefficient was much less variable than had previously en thought. They found slight differences between species and practi- lly no differences between varieties in this respect.

It is quite probable that the characteristics which make one corn riety more drouth tolerant than another are much smaller in magnitude an those that exist among the different genera or species. In order to asure such small differences, specialized equipment had to be develop- . One of the major steps forward in this respect was the development a practical drouth chamber. With some refinements, many scientists e obtained valid experimental results using this type of machine. e use of drouth chambers has not been widely practiced as a means of sting breeding material.

Drouth studies on grass seedlings were conducted by McAllister 1). He found very significant differences in seedling soil drouth sistance between different species, and strains within a species. The riability found within a species suggests the possibility of breeding for soil drouth resistance in grasses.

The first description of the effects of artificial drouth on inbred lines of corn was given by Hunter <u>et al.</u> (6). They found that the relative resistance of corn seedlings tested in a drouth chamber was similar to that noted in the field. Heyne and Laude (5) found a very high correlation between seedling age and drouth resistance. Until the seedlings were 10 days of age, they were very drouth resistant. The drouth resistance decreased sharply and then gradually increased again as the root system developed. This sharp break in resistance came at the time the food reserves of the seed were exhausted. Misra (12) tested the reaction of corn and wheat plants under drouth conditions. His results show that hardened plants survive better than non-hardened ones and that after two weeks of age, the relative drouth tolerance was about the same regardless of age at which tested. He found definite strain differences which could be ascertained by testing. The more drouth tolerant strains located in this manner could be included in a practical plant breeding program.

Tatum (16) was able to make many valuable field observations of drouth damage in Kansas during the recent severe drouth conditions in that state. He noted that there are definite varietal differences in respect to leaf firing. He also observed a tendency for the lines showing the greatest resistance to leaf firing to have somewhat more barren stalks. He concluded that strong selection pressure must be exerted against barrenness in a breeding program where drouth tolerance is one of the objectives.

Corn and sorghums have been grown under relatively similar conditions in this country for many years. Sorghums have shown a marked superiority in drouth resistance when compared with corn. Martin (10) reported that sorghum leaves have more and smaller stomata than corn. The leaves have a waxy cuticular layer which may greatly reduce transpiration when the stomata are closed. Sorghums tend to have more secondary roots than corn. The osmotic concentration of the sorghum leaf juice is lower, while that of the roots, crown, and stalk is higher than corn.

Lonnquist _et al._ (9) showed the practical value of obtaining drouth resistant inbreds. From their work, they were able to show that resistant inbreds, as well as their single crosses, set more seed and their silks remained receptive longer than did drouth susceptible lines and their crosses. Heyne and Brunson (4) found heat and drouth tolerance of corn lines to be intermediate to dominant in its inheritance. They also were able to show that hybrid vigor in itself does not make a cross resistant to drouth. Jenkins and Richey (7) were able to show drouth resistance to be inherited as a dominant. Sayre (13) while working with pure lines of corn and their hybrids found that lines susceptible to drouth injury transmitted this susceptibility to their hybrids. From these results it seems quite clear that once drouth resistant lines are isolated they can be incorporated into a program of plant breeding with little difficulty.

MATERIALS AND METHODS

The experiments reported in this paper were conducted using 40 inbred lines of corn currently being maintained in the plant breeding program at South Dakota State College. Thirty-two of these lines were the same as those tested by Jensen (8). They were used so that any information gained from this series of experiments could be added to that which is already known about the inbreds. Several inbreds developed more recently at South Dakota State College were also included in the tests. For more information about the parental background of the lines, see appendix table I.

The experiments reported in this study can be divided into three primary groups:

(1) Plants tested under field conditions.

(2) Plants tested in a greenhouse bench.

(3) Plants tested in flats.

Plants Tested Under Field Conditions

With drouth under natural conditions being quite variable, it is often difficult to get drouth notes unless some means of control of the environment can be accomplished. With this in mind, the field plot planted at Brookings, South Dakota, in 1957 was designed so that polyethylene sheets 4 mil thick could be placed between the rows to drain off any moisture that might come during the growing season. During dry weather the sheets were removed from the plots to permit the plants to grow under conditions more closely approximating those in the field. The strips of polyethylene were cut in such a way that they overlapped and were tight enough around the plants to give an effective water seal. The test consisted of six replications with the varieties planted in rows 15 inches apart and having 12 inches between plants in the row. In order to get uniform stands, the planting rate was three per hill, thinned after emergence to one typical plant. Three additional rows were planted around the test to act as a border. Prior to planting the soil was plowed and harrowed according to accepted cultural practices in the area. Due to the difficulty of accurately predicting when rains were coming, this method of inducing drouth, although quite effective, was rather hazardous.

Since drouth conditions are generally more prevalent in central and western South Dakota than at Brookings, plantings were made without soil covers at the Range Field Station at Cottonwood, and at the Central Substation at Highmore, South Dakota, during the summer of 1957. Because of above-normal rainfall, none of the plants at either location showed any visible drouth stress.

In 1958, field plantings were made at Brookings and Highmore. In these plantings the seeding rate was eight seeds per hill in rows 42 inches apart and with 42 inches between hills. After emergence, the stand was thinned to five uniform plants per hill. This stand, combined with low rainfall, proved to be sufficient to create a good drouth stress at Brookings. The planting was lost at Highmore because of poor seedling emergence.

Plants Tested in a Greenhouse Bench

These experiments consisted of growing the 40 inbred lines in a greenhouse bench 5 by 24 feet with soil approximately six inches deep. This was done to determine if plants of approximately the same age would respond to drouth under greenhouse conditions in the same way they had in the field. The soil used was a mixture of three parts field topsoil and two parts sand. A sheet of polyethylene was placed between the soil and the bottom and sides of the bench to reduce the border effects normally found under greenhouse bench conditions. In order to facilitate adequate drainage, holes were punched at uniform intervals in the plastic which covered the bottom of the bench. The plastic seemed to be quite effective in holding the environmental variability to a minimum. The planting rate was three seeds per hill with the subsequent stand being thinned to one typical plant. Due to limited bench space the experiment consisted of only four replications with each hill being one plot. The outside row of plants was used only as a border. The plants were grown under optimum moisture conditions to approximately 30 days of age, then watered until drainage occurred from the entire bench. They were then allowed to grow until evaporation and transpiration reduced the soil moisture sufficiently for a drouth stress to occur. On four dates, as the drouth stress increased, notes were taken on appearance of drouth tolerance, leaf rolling, and leaf firing. After the plants had died, the above-ground portions of the plants were harvested and dry matter weights taken to see if plant size correlated with drouth tolerance.

Plants Tested in Flats

The third series of tests was designed to see if the drouth response of plants grown in flats, either in the greenhouse or outdoors, would correlate with field results. The 40 inbred lines were planted in 10 galvanized steel flats 20 by 30 inches with $2\frac{1}{2}$ inches of soil. The flats were planted such that each could act as a replicate containing all of the lines. The rate of planting was three kernels per hill followed by thinning after emergence to two plants, which was the individual plot size. An additional row of one of the inbreds was planted around the edge of each flat to act as a border. The plants were grown to 18 days of age, then watered to completely saturate the soil, and permitted to dry until a drouth stress occurred. At the time of this last watering, five of the flats were removed from the greenhouse and placed outdoors in a relatively protected area to keep wind damage to a minimum. Due to differences in microclimate, the plants placed outdoors showed a drouth stress sooner than those in the greenhouse. This permitted taking drouth notes somewhat earlier on these. Following this, an extremely hot day forced both lots into a severe drouth stress which permitted only one more series of notes to be taken. The plants were watered when it appeared that 50 per cent mortality had occurred. This proved to be approximately correct for the plants outdoors, but was too late for those in the greenhouse where all of the plants were dead. Survival notes were taken on the plants that lived through the outdoor drouth treatment. Because of the large number of dead plants, an arc sine transformation of these data was used to facilitate statistical analysis.

Several additional flats, each row planted to a different inbred, were also subjected to drouth stress. It was hoped from this to more easily detect any differences displayed by the lines.

The design used in all of the experiments was a randomized block. The number of replications varied from four to six depending on the available space and other facilities. In most cases the data collected consisted of visual ratings of the plants from 1 to 5 with 1 being the most desirable and 5 the least desirable expression of the characteristics being studied. Data were collected on the following plant characteristics: appearance of drouth tolerance, leaf rolling, and leaf firing. Some supplemental information on plant weight and plant survival following drouth was also obtained. The appearance of drouth tolerance rating was based on a visual summation of the desirable and undesirable characteristics displayed by the plants while subjected to a drouth stress. Included in this summation are rolling, drooping, firing of the leaves, luster, plant color, and any other characteristics which tended to make a variety appear to be under stress. Leaf rolling data indicate the amount of rolling of the leaves from the edges to the center of the leaf as well as any helical twisting that was displayed. Leaf firing data are based on the amount of necrosis of the leaves. In the 1957 field planting, a value of two was given each dead leaf and one for each showing some degree of firing. The total of dead and fired leaves was the rating given a variety. In subsequent observations a rating of 1 to 5 was used for firing.

With data available covering several different environmental conditions, correlations were obtained to see if results from any or all of the conditions could be used as reliable indications of drouth tolerance.

EXPERIMENTAL RESULTS

Plants Tested Under Field Conditions

Appearance:[1] During the summers of 1957 and 1958, data were obtained on appearance of drouth tolerance on field plantings made at Brookings, South Dakota. The tests contained six replications of the 40 inbred lines.

TABLE I. MEANS FOR APPEARANCE OF 40 INBRED CORN LINES TESTED UNDER FIELD CONDITIONS DURING THE SUMMER OF 1957 WITH DROUTH INDUCED BY A POLYETHYLENE SOIL COVER

Line	Mean appearance rating 7/10/57	7/15/57	7/27/57	8/14/57	Mean
40	1.17	1.17	2.00	1.08	1.35
15	1.33	1.17	2.17	2.25	1.73
2	2.33	2.00	1.33	1.33	1.75
18	1.17	2.00	2.00	1.92	1.77
37	2.00	1.50	1.92	2.08	1.87
5	1.67	1.83	1.67	2.50	1.92
1	2.00	1.92	1.92	2.08	1.96
19	1.17	1.33	2.17	3.17	1.96
25	1.67	2.00	1.58	2.67	1.96
21	1.50	2.50	2.33	1.75	2.02
4	1.67	2.33	2.50	1.67	2.04
38	1.00	2.00	3.00	2.67	2.17
8	1.17	1.83	2.75	3.00	2.19
14	1.33	2.67	2.67	2.17	2.21
30	2.00	2.50	2.25	2.33	2.27
35	2.50	2.50	2.08	2.08	2.29
36	2.33	2.50	2.50	1.92	2.31
39	1.67	2.83	2.67	2.08	2.31
10	1.17	1.67	3.25	3.25	2.33

[1]To add brevity to this paper, appearance and appearance of drouth tolerance will be used synonymously.

Line		7/10/57	7/15/57	7/27/57	8/14/57	Mean
		Mean appearance rating				
23		1.83	2.33	3.08	2.08	2.33
29		2.33	3.00	2.25	1.92	2.38
17		1.50	2.00	2.58	3.50	2.40
27		2.00	2.83	2.25	2.58	2.42
6		2.33	1.50	2.75	3.17	2.44
24		2.00	2.50	2.92	2.33	2.44
11		1.17	2.33	2.50	3.83	2.46
12		2.17	2.17	2.67	2.83	2.46
31		3.00	2.67	2.33	2.08	2.52
9		1.33	1.83	3.17	3.83	2.54
22		1.83	2.67	3.25	2.50	2.56
33		1.83	3.00	3.25	2.17	2.56
26		2.67	2.83	2.25	2.75	2.62
7		1.00	3.00	2.58	4.00	2.64
32		2.00	2.17	2.83	3.58	2.64
13		2.17	3.33	2.42	3.08	2.75
3		2.50	3.33	3.25	2.08	2.79
28		2.83	4.00	2.50	2.42	2.94
34		3.17	3.67	3.33	2.42	3.15
20		2.33	3.50	3.75	3.08	3.16
16		2.17	3.67	3.08	4.00	3.23
	d. f.	Mean square				
Lines	39	1.93**	2.95**	1.27**	3.06**	
Replications	5	.27	.61	2.44**	.77	
Error	195	.28	.34	.32	.44	

**Significant at the one per cent level.

TABLE II. ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES TESTED IN THE FIELD UNDER POLYETHYLENE INDUCED DROUTH CONDITIONS

Source of variation	d. f.	Mean square
Lines	39	3.97**
Dates	3	24.77**
Replications	5	.72
Lines x Dates	117	1.89**
Lines x Replications	195	.51**
Dates x Replications	15	1.13**
Error	585	.35
Total	959	

**Significant at the one per cent level.

TABLE III. MEANS FOR APPEARANCE OF 40 INBRED CORN LINES TESTED UNDER FIELD CONDITIONS DURING THE SUMMER OF 1958

Line	Mean appearance rating	Line	Mean appearance rating
40	1.00	17	2.83
39	1.17	30	2.83
15	1.67	10	3.00
21	1.83	14	3.00
23	2.00	24	3.00
33	2.00	26	3.00
1	2.00	7	3.17
5	2.17	13	3.17
35	2.17	31	3.17
29	2.17	37	3.17
6	2.33	2	3.33
19	2.33	34	3.33
22	2.33	16	3.50
8	2.50	38	3.50
25	2.50	27	3.67
9	2.67	28	2.83
18	2.67	32	3.83
4	2.83	3	4.00
11	2.83	36	4.17
12	2.83	20	4.33

TABLE IV. ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES TESTED IN THE FIELD DURING THE SUMMER OF 1958

Source of variation	d. f.	Mean square
Lines	39	3.53**
Replications	5	.63
Error	195	.77
Total	239	

**Significant at the one per cent level.

A highly significant correlation of .583 was obtained for appearance of drouth tolerance in the field during the summers of 1957 and 1958. An examination of tables I and II shows that lines 1, 5, 15, and 40 looked very good in the field both years. Lines 2, 33, and 37 were quite variable from one year to the next, while 3, 16, 20, and 28 looked very poor both years.

Leaf rolling: Data on the amount of leaf rolling displayed by corn plants under field drouth conditions were obtained from the same plots as those used to obtain the appearance of drouth tolerance information. Data were collected only once each year, on August 15, 1957 and on August 21, 1958. By these dates, a substantial degree of leaf rolling was manifest.

TABLE V. MEAN LEAF ROLLING OF 40 INBRED CORN LINES TESTED UNDER FIELD CONDITIONS DURING THE SUMMER OF 1957 WITH DROUTH INDUCED BY A POLYETHYLENE SOIL COVER

Line	Mean leaf rolling	Line	Mean leaf rolling
8	1.17	21	2.67
40	1.17	32	2.67
15	1.33	37	2.67
19	1.67	5	2.83
10	1.83	26	2.83
31	1.83	30	2.83
1	2.00	4	3.00
9	2.00	11	3.00
35	2.00	13	3.00
38	2.00	24	3.00
6	2.17	27	3.00
17	2.17	29	3.00
2	2.33	33	3.00
7	2.33	16	3.17
14	2.33	22	3.17
25	2.33	23	3.17
36	2.50	34	3.33
39	2.50	3	3.67
12	2.67	28	4.33
18	2.67	20	4.33

TABLE VI. ANALYSIS OF VARIANCE FOR LEAF ROLLING OF 40 INBRED CORN LINES GROWN IN THE FIELD IN 1957 WITH DROUTH INDUCED BY A POLYETHYLENE SOIL COVER

Source of variation	d. f.	Mean square
Lines	39	3.05**
Replications	5	.97
Error	195	.60
Total	239	

**Significant at the one per cent level.

TABLE VII. MEAN LEAF ROLLING OF 40 INBRED CORN LINES TESTED UNDER FIELD CONDITIONS DURING THE SUMMER OF 1958

Line	Mean leaf rolling	Line	Mean leaf rolling
15	1.17	2	3.00
40	1.17	9	3.00
39	1.33	11	3.00
21	1.50	12	3.00
5	1.67	14	3.00
29	1.83	31	3.00
1	2.00	32	3.00
8	2.00	35	3.00
19	2.00	4	3.17
33	2.00	17	3.17
18	2.33	24	3.17
34	2.33	25	3.17
22	2.50	10	3.33
23	2.50	37	3.67
30	3.50	27	3.83
6	2.67	38	3.83
13	2.67	3	4.00
7	2.83	20	4.00
16	2.83	28	4.00
26	2.83	36	4.17

TABLE VIII. ANALYSIS OF VARIANCE FOR LEAF ROLLING OF 40 INBRED CORN LINES GROWN IN THE FIELD DURING THE SUMMER OF 1958

Source of variation	d. f.	Mean square
Lines	39	3.82**
Replications	5	1.61
Error	195	.85
Total	239	

**Significant at the one per cent level.

The correlation coefficient of .427, found between leaf rolling in the field in 1957 and 1958 was significant at the one per cent level. Lines 1, 8, 15, and 40 displayed very little leaf rolling either year. Lines 3, 20, and 28 on the other hand, displayed very severe leaf rolling both years.

Leaf firing: Data on the amount of leaf firing was obtained on August 14, 1957. The rating system used was two for each dead leaf and one for each leaf showing a lesser degree of firing. No readings were obtained in 1958 due to insufficient firing by the time the plants were starting to mature. Any firing data after that time would have been confounded by the natural drying of the plants.

TABLE IX. MEAN LEAF FIRING OF 40 INBRED CORN LINES GROWN DURING THE SUMMER OF 1957 WITH DROUTH INDUCED BY A POLYETHYLENE SOIL COVER

Line	Mean leaf firing	Line	Mean leaf firing
40	1.33	19	4.17
15	2.83	21	4.17
28	2.83	23	4.17
36	2.83	33	4.17
2	3.00	35	4.17
31	3.00	37	4.17
22	3.17	38	4.17
27	3.33	18	4.50
4	3.50	24	4.50
3	3.67	26	4.50
25	3.67	30	4.50
10	3.83	5	4.67
29	3.83	6	4.67
39	4.00	34	4.83
14	4.17	7	5.00

ne	Mean leaf firing	Line	Mean leaf firing
	5.17	16	6.17
	5.33	17	6.17
	5.33	12	6.33
	5.50	9	7.33
	6.00	11	8.00

BLE X. ANALYSIS OF VARIANCE FOR LEAF FIRING OF 40 INBRED CORN LINES GROWN DURING THE SUMMER OF 1957 WITH DROUTH INDUCED BY A POLYETHYLENE SOIL COVER

urce of variation	d. f.	Mean square
nes	39	9.97**
plications	5	7.21**
ror	195	1.46
tal	239	

Significant at the one per cent level.

It can be seen from table IX that lines 15, 28, and 40 showed ttle leaf firing while lines 5 and 8 had much evidence of it. The all amount of firing displayed by lines 15 and 40, combined with their od ratings on leaf rolling, were factors in their high appearance of outh tolerance rating during the summer of 1957. Line 28, although it owed little leaf firing, tended to wilt and leaf roll very severely, ich contributed to its very poor rating for appearance of drouth tol- ance. Lines 5 and 8, even though the lower leaves burned badly, show- very little leaf rolling which helped them retain a fairly good over- l rating.

Correlations were calculated on the data obtained in the field in 1957 and 1958. The correlation coefficients are presented in table XI.

TABLE XI. CORRELATION COEFFICIENTS BETWEEN APPEARANCE, LEAF FIRING, AND LEAF ROLLING OF 40 INBRED CORN LINES GROWN IN THE FIELD DURING THE SUMMERS OF 1957 AND 1958

	Appearance 1957	Appearance 1958	Leaf rolling 1957	Leaf rolling 1958
Appearance 1958	.583**			
Leaf rolling 1957	.648**	.504**		
Leaf rolling 1958	.432**	.863**	.427**	
Leaf firing 1957	.402**	.179	.156	.108

**Significant at the one per cent level.

Very good correlation between 1957 and 1958 field plot data was obtained. All combinations of appearance of drouth tolerance and leaf rolling showed highly significant correlations both years. The highly significant correlations between leaf rolling and appearance may be biased toward each other even though the author made no deliberate attempt to rate a line poor in appearance simply because it showed leaf rolling. Generally when leaf rolling occurred, other undesirable effects such as wilting and lack of luster were also present and the combination of all of the deleterious factors made up the appearance rating. The observations of leaf rolling and appearance were taken on separate days in 1957. Both were taken at the same time in 1958 which might account in part for the high correlation, .863, noted that year.

Leaf firing had a highly significant correlation with appearance in 1957. The correlations between leaf firing in 1957 and appearance in 1958 and leaf rolling in 1957 and 1958 were positive, but were not great enough to be significant. With very little leaf firing in 1958, the obvious result was that leaf rolling, wilting and other features contributed more to the appearance of drouth tolerance rating. If leaf firing had been present, the 1958 appearance rating might have reflected this enough to obtain a higher correlation between leaf firing in 1957 and appearance in 1958 than the .179 which was obtained.

Plants Tested in a Greenhouse Bench

A series of experiments was initiated during the winter of 1958 in an attempt to see if corn varieties subjected to drouth in a greenhouse bench would respond the same as when grown in the field. The first planting was made Feb. 16, 1958. The greenhouse temperature was maintained as near as possible to 70°F. On warm sunny days the temperature rose considerably above this. In order to maintain a 16 hour daylight period, four 300 watt electric lights, regulated by time clocks, were suspended above the bench.

A low correlation of .084 between appearance in the field in 1957 and the first bench planting was obtained. This prompted the author to make a second bench planting immediately after the plants were removed from the first experiment.

Appearance of drouth tolerance: Data were collected on the appearance of drouth tolerance in a manner similar to that used in the field. The same criteria were used in arriving at an appearance value.

TABLE XII. MEAN APPEARANCE RATING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH EXPERIMENT

Line	Mean appearance rating 4/7/58	4/9/58	4/14/58	4/20/58	Mean
35	1.25	2.00	1.00	1.50	1.44
2	1.75	1.25	2.00	1.75	1.69
26	2.00	2.00	2.50	2.50	2.25
33	2.25	2.25	2.50	2.00	2.25
3	2.00	2.00	3.00	2.00	2.25
6	2.25	2.50	2.25	2.25	2.31
8	2.00	1.50	2.75	3.25	2.37
39	2.25	2.25	2.25	2.75	2.37
20	2.25	2.25	2.50	3.00	2.50
9	2.75	2.50	2.75	2.75	2.69
32	3.00	3.25	2.00	2.50	2.69
1	2.75	2.50	2.75	3.00	2.75
4	2.50	2.75	2.75	3.00	2.75
15	2.00	2.50	3.25	3.50	2.81
21	2.75	2.50	3.00	3.00	2.81
7	3.25	2.75	3.00	2.75	2.94
22	3.25	2.75	3.00	2.75	2.94
27	2.75	2.75	3.25	3.00	2.94
19	3.00	3.25	2.75	3.00	3.00
40	2.75	3.00	3.50	2.75	3.00
13	3.00	2.75	3.50	3.00	3.06
24	2.75	3.50	3.50	2.50	3.06
17	3.50	3.25	2.75	2.75	3.06
18	3.00	2.75	3.75	3.00	3.12
12	3.00	2.75	3.50	3.50	3.19
30	2.75	3.00	3.00	4.25	3.25
5	3.25	2.50	3.75	3.50	3.25
31	3.25	3.00	3.75	3.00	3.25
37	3.00	3.00	3.25	4.00	3.31
25	2.50	2.75	3.75	4.25	3.31
34	3.50	3.00	3.25	4.00	3.44
16	3.25	3.25	3.75	3.50	3.44
14	3.00	3.25	4.00	3.50	3.44
38	3.25	3.50	3.75	3.50	3.50
23	4.00	3.25	4.00	3.00	3.56
28	3.75	3.50	4.00	3.50	3.69

Line	d. f.	Mean appearance rating 4/7/58	4/9/58	4/14/58	4/20/58	Mean
10		3.25	4.25	4.00	4.00	3.88
29		3.75	3.25	4.25	4.25	3.88
11		4.50	4.50	4.00	4.00	4.25
36		4.50	4.25	4.50	4.00	4.31
	d. f.	Mean square				
Lines	39	1.92**	1.78**	2.76**	1.90**	
Replications	3	1.21	.76	2.12**	1.13	
Error	117	.63	.41	.48	.59	

**Significant at the one per cent level.

TABLE XIII. ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH EXPERIMENT

Source of variation	d. f.	Mean square
Lines	39	5.98**
Replications	3	3.26**
Dates	3	3.72**
Lines x Dates	117	.94**
Lines x Replications	117	.60**
Dates x Replications	9	.87*
Error	351	.39
Total	639	

**Significant at the one per cent level.
*Significant at the five per cent level.

TABLE XIV. MEAN APPEARANCE RATING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE SECOND GREENHOUSE BENCH EXPERIMENT

Line	Mean appearance rating 6/24/58	6/26/58	Mean
6	1.75	1.50	1.63
19	1.25	2.00	1.63
40	2.00	1.50	1.75
16	1.75	2.25	2.00
5	1.75	2.50	2.13
13	2.25	2.00	2.13
15	2.00	2.25	2.13
25	2.50	1.75	2.13
20	1.75	2.75	2.25
21	2.25	2.25	2.25
23	2.50	2.25	2.38
27	2.50	2.25	2.38
8	3.00	2.00	2.50
9	2.75	2.25	2.50
12	3.00	2.25	2.63
22	2.25	3.00	2.63
31	2.25	3.00	2.63
32	2.25	3.00	2.63
37	2.50	2.75	2.63
3	2.75	2.75	2.75
33	2.25	3.25	2.75
39	2.50	3.00	2.75
4	3.00	2.75	2.88
34	3.00	2.75	2.88
35	3.00	2.75	2.88
1	3.00	3.00	3.00
26	3.50	2.50	3.00
18	3.25	3.00	3.13
14	3.25	3.25	3.25
17	3.00	3.50	3.25
2	3.25	3.50	3.38
7	3.00	3.75	3.38
10	2.75	4.00	3.38
29	3.00	3.75	3.38
36	3.75	3.00	3.38
11	4.00	3.00	3.50
24	3.75	3.25	3.50
30	3.50	3.50	3.50
38	4.50	3.25	3.88
28	4.75	4.50	4.63

Line		Mean appearance rating 6/24/58	6/26/58	Mean
	d. f.	Mean square		
Lines	39	3.54**	1.78**	
Replications	3	4.62**	2.71**	
Error	117	.40	.60	

**Significant at the one per cent level.

TABLE XV. ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE SECOND GREENHOUSE BENCH EXPERIMENT

Source of variation	d. f.	Mean square
Lines	39	14.08**
Replications	3	6.97**
Dates	1	.01
Lines x Dates	39	.79**
Lines x Replications	117	1.05**
Dates x Replications	3	.38
Error	117	.39
Total	319	

**Significant at the one per cent level.

A high degree of inconsistency existed between the first and second bench plantings. The positive but not significant correlation of .293 shows this quite clearly. Inbreds 2, 5, 16, and 26 displayed a large part of this variability, looking good in one experiment and very poor in the other. Several lines, 6, 8, 9, and 20 showed up well in both tests, while lines 11, 28, 36, and 38 looked very poor in both cases. No explanation can be given for the inconsistency of some lines in these experiments.

Leaf rolling: Leaf rolling data were collected on the plants growing in the greenhouse bench at the same time the appearance notes were taken. As in the field, these data were a summation of all of the leaf rolling displayed by the plants.

TABLE XVI. MEAN LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH PLANTING

Line	Mean leaf rolling 4/7/58	4/9/58	4/14/58	4/20/58	Mean
2	1.75	1.75	1.75	1.75	1.75
3	1.50	1.75	2.00	1.75	1.75
8	1.75	1.50	1.75	2.00	1.75
20	1.75	2.25	1.75	1.50	1.81
35	1.50	1.75	2.00	2.00	1.81
26	1.75	1.50	2.25	2.25	1.94
30	1.75	1.25	2.00	3.00	2.00
4	2.25	2.50	1.50	2.00	2.06
12	1.75	2.25	2.25	2.00	2.06
15	2.00	2.00	2.50	2.25	2.19
39	2.25	2.25	1.75	2.50	2.19
22	1.75	2.50	2.25	2.50	2.25
24	2.75	1.75	2.75	1.75	2.25
34	1.75	2.00	2.75	2.50	2.25
6	2.25	2.25	2.75	2.00	2.31
18	2.00	2.00	2.25	3.00	2.31
38	2.25	2.75	2.50	2.00	2.38
14	2.25	2.25	2.75	2.50	2.44
9	2.00	2.50	3.00	2.50	2.50
1	2.75	3.25	2.25	2.75	2.75
25	2.00	3.00	2.50	3.50	2.75
21	3.00	3.00	2.50	3.00	2.88
23	3.00	3.00	3.00	2.50	2.88
27	2.25	3.00	3.50	3.00	2.94
5	2.25	2.75	3.50	3.50	3.00
33	2.25	2.75	3.50	3.50	3.00
19	2.75	2.75	3.00	4.00	3.12
13	3.25	3.00	3.00	3.75	3.25
28	2.25	3.25	3.50	4.00	3.25
29	2.00	3.00	4.00	4.00	3.25
36	3.25	3.50	3.50	3.00	3.31
40	3.00	3.75	3.75	3.50	3.50

Line		Mean leaf rolling 4/7/58	4/9/58	4/14/58	4/20/58	Mean
16		3.25	3.25	4.25	3.50	3.56
37		3.25	3.25	4.25	3.50	3.56
7		3.25	3.50	4.00	4.25	3.75
11		3.75	4.25	4.00	3.00	3.75
32		3.50	4.00	3.25	4.25	3.75
31		3.25	3.75	4.75	3.50	3.81
10		3.75	3.75	4.25	3.75	3.88
17		3.75	4.25	4.75	4.25	4.25
	d. f.	Mean square				
Lines	39	1.81**	2.54**	3.08**	2.95**	
Replications	3	.75	1.79*	.32	.07	
Error	117	.62	.55	.68	.61	

**Significant at the one per cent level.
*Significant at the five per cent level.

TABLE XVII. ANALYSIS OF VARIANCE FOR LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH PLANTING

Source of variation	d. f.	Mean square
Lines	39	8.26**
Replications	3	1.97**
Dates	3	8.07**
Lines x Dates	117	.71**
Lines x Replications	117	1.13**
Dates x Replications	9	.32
Error	351	.45
Total	639	

**Significant at the one per cent level.

No leaf rolling notes were taken on the second bench experiment, since very little rolling was apparent at the time the appearance notes were taken. Due to the absence of the author from Brookings, South

Dakota, after June 26, 1958, it was impossible to get any more data from the experiment other than dry weights of the forage produced. These data were gathered by another worker and relayed to the author.

Leaf firing: Leaf firing data were taken on only three dates due to insufficient firing by the time the first appearance and leaf rolling notes were taken. On some plants nearly every leaf had the tips burned, on others only the lower three or four leaves were severely burned, while others showed no firing at all. Due to the divergent phenotypic response of different varieties, a rigid system of values such as two for each dead leaf and one for each showing some degree of firing did not permit enough expression of degrees of firing. Therefore a rating system of one to five was used.

TABLE XVIII. MEAN LEAF FIRING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH EXPERIMENT

Line	Mean leaf firing 4/9/58	4/14/58	4/20/58	Mean
7	1.25	1.00	1.00	1.08
35	1.00	1.00	1.75	1.25
3	1.25	1.50	1.75	1.50
22	1.00	1.25	2.25	1.50
2	1.00	1.75	2.00	1.58
26	1.50	1.75	1.75	1.67
32	1.50	1.75	2.00	1.75
31	1.50	2.00	2.00	1.83
8	1.25	1.75	2.75	1.92
40	1.75	2.00	2.00	1.92
6	1.50	1.75	2.75	2.00
39	1.75	2.25	2.50	2.17
20	2.25	1.75	2.75	2.25
17	2.00	2.50	2.75	2.42
38	1.25	2.50	3.50	2.42
14	2.25	2.75	2.50	2.50

Line	4/9/58	4/14/58	4/20/58	Mean
	Mean leaf firing			
21	1.75	2.50	3.25	2.50
33	2.00	2.75	2.75	2.50
1	1.75	2.75	3.50	2.67
27	2.25	2.50	3.25	2.67
5	1.75	3.00	3.50	2.75
9	2.00	3.00	3.25	2.75
13	2.00	2.75	3.50	2.75
36	2.25	2.00	4.25	2.83
15	2.00	3.00	4.00	3.00
23	2.75	2.75	3.50	3.00
4	3.00	2.00	4.25	3.00
24	2.75	3.00	3.50	3.08
28	2.75	3.25	3.25	3.08
37	2.00	2.50	4.75	3.08
18	2.75	3.25	3.50	3.17
11	4.25	3.00	3.00	3.42
19	3.00	3.50	3.75	3.42
25	2.50	3.25	4.50	3.42
12	2.75	3.75	4.00	3.50
30	2.75	4.00	4.25	3.67
10	2.75	4.00	4.50	3.75
29	3.00	3.75	4.50	3.75
34	3.25	4.00	4.00	3.75
16	3.75	3.75	4.00	3.83

	d. f.	Mean square		
Lines	39	2.35**	2.76**	3.49**
Replications	3	3.09**	1.71**	2.21**
Error	117	.55	.43	.50

**Significant at the one per cent level.

TABLE XIX. ANALYSIS OF VARIANCE FOR LEAF FIRING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH EXPERIMENT

Source of variation	d. f.	Mean square
Lines	39	6.94**
Replications	3	4.89**
Dates	2	41.79**
Lines x Dates	78	.82**
Lines x Replications	117	.78**
Dates x Replications	6	1.07**
Error	234	.36
Total	479	

**Significant at the one per cent level.

A comparison of tables XII, XVI, and XVIII shows that appearance of drouth tolerance is indicated quite closely by leaf firing and rolling. These tables show that line 35 had the best appearance rating in the first bench experiment, tied for fourth in leaf rolling, and rated second in leaf firing. Line 2 rated second in appearance, tied for first on leaf rolling, and rated fifth in leaf firing. Line 7 on the other hand rated about average on appearance although it had shown the least leaf firing of any line. The rating of this line was materially reduced by the great amount of leaf rolling it displayed. It is apparent that factors other than leaf firing and rolling influenced the appearance rating. This is shown by the fact that lines 14 and 38 rated much below average on appearance, while rating above average for both leaf rolling and firing.

Dry matter produced: In order to see what effect the drouth condition had on plant development and how this effect compared with other observations of the plants, the above-ground portion of all the plants was harvested and dry matter determinations made. All weights are reported as grams of dry matter produced.

TABLE XX. AVERAGE PLANT WEIGHT OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH EXPERIMENT

Line	Grams	Line	Grams
19	1.88	33	4.64
8	2.17	10	4.70
37	2.38	2	4.76
30	2.54	21	4.89
25	2.85	9	5.06
38	2.85	12	5.31
11	2.98	4	5.49
39	3.08	14	5.57
28	3.11	22	5.64
18	3.45	15	5.70
23	2.66	27	5.72
5	3.79	31	6.55
16	3.88	26	7.16
36	4.08	24	7.39
29	4.19	3	7.69
17	4.25	20	7.93
13	4.29	1	8.25
32	4.61	7	8.35
34	4.61	6	10.54
40	4.61	35	17.76

TABLE XXI. ANALYSIS OF VARIANCE FOR PLANT WEIGHT OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIRST GREENHOUSE BENCH EXPERIMENT

Source of variation	d. f.	Mean square
Lines	39	31.35**
Replications	3	3.93
Error	117	3.22
Total	159	

**Significant at the one per cent level.

TABLE XXII. AVERAGE PLANT WEIGHT OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE SECOND GREENHOUSE BENCH EXPERIMENT

Line	Grams	Line	Grams
39	1.36	32	3.90
28	1.38	34	3.92
11	1.68	30	3.93
7	2.07	21	3.94
22	2.72	16	3.97
25	2.77	29	4.07
8	3.01	12	4.11
17	3.15	5	4.19
19	3.23	14	4.19
18	3.29	13	4.28
38	3.32	24	4.46
37	3.35	31	4.59
10	3.43	27	4.71
33	3.47	40	4.78
23	3.54	3	5.19
15	3.57	26	5.30
9	3.59	20	5.60
2	3.71	1	6.24
4	3.79	6	7.11
36	3.81	35	7.45

TABLE XXIII. ANALYSIS OF VARIANCE FOR PLANT WEIGHT OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE SECOND GREENHOUSE BENCH EXPERIMENT

Source of variation	d. f.	Mean square
Lines	39	6.74**
Replications	3	3.70*
Error	117	1.22
Total	159	

**Significant at the one per cent level.
*Significant at the five per cent level.

TABLE XXIV. CORRELATION COEFFICIENTS BETWEEN APPEARANCE, LEAF FIRING, LEAF ROLLING, AND PLANT WEIGHTS OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN A GREENHOUSE BENCH

	First planting			Second planting	
	Leaf rolling	Leaf firing	Plant weight	Appearance	Plant weight
First planting					
Appearance	.377*	.656**	-.565**	.293	-.471**
Leaf rolling		.193	-.193	.004	-.297
Leaf firing			-.520**	.065	-.282
Plant weight				.069	.727**
Second planting					
Appearance					-.355*

**Significant at the one per cent level.
*Significant at the five per cent level.

A highly significant correlation of .727 was obtained between plant weights in the first and second greenhouse bench experiments.

Negative correlations between appearance and plant weight indicates that smaller plants suffered the effects of the drouth stress more severely than did larger plants. Lines 8 and 39 were exceptions to this rule. Plants of these lines were much smaller than average but still gave about average appearance ratings.

Although the analysis of variance of the data from the bench plantings were highly significant, there were enough differences between the first and second planting that only two correlations showed significance. A negative correlation of -.471 was found between appearance in the first planting and plant weight in the second. This indicates that the smaller plants showed the most severe drouth stress. The highly significant correlation found between plant weight in the first and second bench planting was obtained even though the plant weights were considerably lighter in the second experiment. The correlation between appearance and leaf rolling was .377. This was significant at the five per cent level. Leaf rolling did not seem to play nearly as large a roll in appearance in the greenhouse as it had in the field. The impression the author received from observing the plants was that a greater degree of leaf rolling from the edges to the center of the leaves occurred in the greenhouse than had occurred in the field. This greater amount of leaf rolling was not visibly associated with greater drouth stress. In some cases, it appeared to be a protective mechanism by which less leaf surface was exposed, thus limiting transpiration even though the leaves retained a high degree of turgor.

Plants Tested in Flats

A series of experiments to compare seedling drouth tolerance with that observed in the field was initiated in the spring of 1958. Since the responses in the greenhouse bench experiments had not compared too favorably with that in the field, it was decided to subject half of the flats to drouth in the greenhouse and the remainder were placed outside. Leaf firing and rolling data were collected from both experiments. Survival after watering was also obtained from the flats dried outside.

Appearance of drouth tolerance: Appearance data were collected in a manner similar to that used in previous experiments.

TABLE XXV. MEAN APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS IN THE GREENHOUSE

Line	Mean appearance rating	Line	Mean appearance rating
23	1.60	33	3.00
18	1.80	37	3.00
21	1.80	1	3.20
36	2.20	11	3.20
4	2.40	19	3.20
34	2.40	20	3.20
12	2.60	37	3.20
31	2.60	26	3.40
38	2.60	29	3.40
2	2.80	13	3.60
8	2.80	15	3.60
9	2.80	32	3.60
14	2.80	35	3.60
30	2.80	5	3.80
39	2.80	7	3.80
40	2.80	25	3.80
3	3.00	16	4.00
6	3.00	22	4.00
17	3.00	28	4.20
24	3.00	10	4.40

TABLE XXVI. ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS IN THE GREENHOUSE

Source of variation	d. f.	Mean square
Line	39	2.06**
Replications	4	.62
Error	156	.66
Total	199	

**Significant at the one per cent level.

TABLE XXVII. MEAN APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE

Line	Mean appearance rating 5/21/58	5/23/58	Mean
21	1.00	2.40	1.70
18	1.60	2.20	1.90
4	1.40	2.60	2.00
8	2.00	2.00	2.00
12	1.60	2.40	2.00
15	1.80	2.20	2.00
14	2.20	2.00	2.10
17	1.80	2.60	2.20
6	2.00	2.60	2.30
9	2.60	2.00	2.30
23	1.80	2.80	2.30
38	2.20	2.40	2.30
40	1.80	2.80	2.30
5	2.80	2.00	2.40
19	1.80	3.00	3.40
30	2.20	2.60	2.40
34	1.60	3.20	2.40
2	2.00	3.00	2.50
20	3.00	2.00	2.50
36	2.60	2.40	2.50
7	2.00	3.20	2.60
27	2.20	3.00	2.60
32	2.00	3.20	2.60

Line	Mean appearance rating 5/21/58	5/23/58	Mean
1	2.80	2.60	2.70
3	2.20	3.20	2.70
39	1.40	4.00	2.70
11	2.40	3.20	2.80
37	2.40	3.20	2.80
24	3.00	2.80	2.90
26	3.40	2.60	3.00
29	2.80	3.20	3.00
35	3.00	3.00	3.00
22	2.00	4.20	3.10
31	4.20	2.00	3.10
28	3.00	3.40	3.20
33	3.20	3.40	3.30
10	3.00	4.20	3.60
25	2.80	4.40	3.60
13	4.20	3.20	3.70
16	4.00	3.80	3.90

	d. f.	Mean square	
Lines	39	2.83**	2.09**
Replications	4	.33	2.58**
Error	155	.62	.49

**Significant at the one per cent level.

TABLE XXVIII. ANALYSIS OF VARIANCE FOR APPEARANCE OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE

Source of variation	d. f.	Mean square
Lines	39	2.74**
Replications	4	1.18
Dates	1	23.04**
Lines x Dates	39	2.15**
Lines x Replications	156	.50
Dates x Replications	4	1.72*
Error	156	.62
Total	399	

**Significant at the one per cent level.
*Significant at the five per cent level.

A highly significant correlation of .593 was found for appearance of plants dried in flats in the greenhouse and outside. This high correlation was obtained despite the fact that two of the lines showed a marked difference in response between the greenhouse and outside. Line 5 rated thirty-fourth when dried in the greenhouse while rating fourteenth in the flats outside. The response displayed by this line outside the greenhouse was nearly the same as when dried under field conditions where it had ranked sixth in 1957 and eighth in 1958. Line 15 ranked thirtieth in the flats dried in the greenhouse and tied for third when dried outside. The outdoor rating of this line was also very similar to that received in the field, where it rated second in 1957 and third in 1958.

Leaf rolling: Data were collected on leaf rolling from the flats dried in the greenhouse at the time the appearance notes were taken. There was little leaf rolling present by the time the first appearance notes were taken outside, hence leaf rolling data were obtained only on the twenty-third of May.

TABLE XXIX. MEAN LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS IN THE GREENHOUSE

Line	Mean leaf rolling	Line	Mean leaf rolling
8	1.20	36	2.00
18	1.20	24	2.20
23	1.20	25	2.20
9	1.40	34	2.20
4	1.60	37	2.20
14	1.60	15	2.40
17	1.60	40	2.40
20	1.60	6	2.60
26	1.60	19	2.60
27	1.60	32	2.60
30	1.60	38	2.60
39	1.60	7	2.80
2	1.80	16	2.80
3	1.80	28	2.80
12	1.80	31	2.80
21	1.80	35	2.80
1	2.00	5	3.00
10	2.00	13	3.00
11	2.00	33	3.00
29	2.00	22	3.20

TABLE XXX. ANALYSIS OF VARIANCE FOR LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS IN THE GREENHOUSE

Source of variation	d. f.	Mean square
Lines	39	1.62**
Replications	4	3.12**
Error	156	.37
Total	199	

**Significant at the one per cent level.

TABLE XXXI. MEAN LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE

Line	Mean leaf rolling	Line	Mean leaf rolling
8	1.20	39	2.80
20	1.20	11	3.00
23	1.20	13	3.00
18	1.40	21	3.00
14	1.60	33	3.00
15	1.80	40	3.00
4	2.00	2	3.20
9	2.00	6	3.20
25	2.00	31	3.20
26	2.00	38	3.20
5	2.20	10	3.40
24	2.20	36	3.60
30	2.20	37	3.60
12	2.40	19	3.80
17	2.40	35	3.80
1	2.60	32	4.00
3	2.60	16	4.40
27	2.80	22	4.40
28	2.80	29	4.40
34	2.80	7	4.80

TABLE XXXII. ANALYSIS OF VARIANCE FOR LEAF ROLLING OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS OUTSIDE

Source of variation	d. f.	Mean square
Lines	39	4.32**
Replications	4	1.10
Error	156	.72
Total	199	

**Significant at the one per cent level.

A highly significant correlation of .649 was found for leaf rolling between flats in the greenhouse and outside. The pattern of leaf rolling shown by lines 5 and 15 was the same as shown for appearance. Both lines rolled heavily in the greenhouse and very little when dried outside. When observing the flats in the greenhouse and outside, it appeared that leaf rolling was accentuated in many lines when dried in the greenhouse. A comparison of the indoor and outside data does not clearly show this except in lines 5 and 15.

Plant survival: Ten days after watering, survival notes were taken on the plants grown in flats in the greenhouse and outside. Only the plants dried outside showed any survival. An arc sine transformation of the data was done to facilitate statistical analysis. The non-transformed data are given in table XXXIII. There was a total of 10 plants of each variety used in the flats dried outside. The number of plants killed was reported since correlations between these values and other data collected would show a positive relationship. This permitted smaller numbers to represent the most desirable expression of the characteristics reported.

Table XXXIII showed that lines 21 and 24 had a significantly higher survival than any of the other lines in the experiment. Line 21 had looked very good in the flats while under a drouth stress. It had rated first in appearance outside and tied for second when dried in the greenhouse. In both cases it had displayed about an average amount of leaf rolling. Line 24 was about average for appearance and leaf rolling both in and out of the greenhouse.

TABLE XXXIII. PLANTS FAILING TO SURVIVE AFTER WATERING 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS DRIED OUTSIDE

Line	Plants not surviving	Line	Plants not surviving
24	1	7	9
21	2	9	9
12	5	13	9
25	5	14	9
6	6	26	9
16	6	30	9
29	6	36	9
35	6	37	9
3	7	38	9
11	7	2	10
19	7	5	10
20	7	10	10
34	7	15	10
4	8	17	10
8	8	22	10
18	8	27	10
25	8	31	10
28	8	32	10
40	8	33	10
1	9	39	10

TABLE XXXIV. ANALYSIS OF VARIANCE FOR PLANTS FAILING TO RECOVER FROM DROUTH TREATMENT IN FLATS OUTSIDE

Source of variation	d. f.	Mean square
Lines	39	4.25**
Replications	4	2.27
Error	156	1.68
Total	199	

**Significant at the one per cent level.

TABLE XXXV. CORRELATION COEFFICIENTS BETWEEN APPEARANCE, LEAF ROLLING, AND SURVIVAL OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN FLATS

	Appearance greenhouse	Leaf rolling greenhouse	Appearance outside	Leaf rolling outside
Leaf rolling greenhouse	.506**			
Appearance outside	.593**	.514**		
Leaf rolling outside	.367*	.649**	.436**	
Survival outside	.259	.127	.136	.082

**Significant at the one per cent level.
*Significant at the five per cent level.

Significant or highly significant correlations were found for all combinations of appearance and leaf rolling in flats dried in the greenhouse and outside. No significance was found for plant survival and either appearance or leaf rolling.

Figures 1 and 2 show flats that were planted with a variety in each row. They were subjected to a severe drouth stress before watering. Several lines had excellent recovery after watering while others were all killed by the treatment.

Correlation coefficients were obtained for various plant characteristics observed in the greenhouse bench and in flats, and data obtained from the field plantings. These correlations appear in table XXXVI.

Figure 1. Variable Recovery of Several Variety Rows of Inbred Corn Lines Following Drouth Treatment

Figure 2. Recovery of Inbred Lines of Corn Following Drouth Treatment

TABLE XXXVI. CORRELATION COEFFICIENTS OF 40 INBRED CORN LINES SUBJECTED TO DROUTH IN THE FIELD, IN A GREENHOUSE BENCH, AND IN FLATS

	Appearance 1957	Appearance 1958	Leaf rolling 1957	Leaf rolling 1958	Leaf firing 1957
Appearance first bench	.084	.204	.141	.178	.053
Leaf firing first bench	.022	.001	.169	-.038	.200
Leaf rolling first bench	.041	.041	-.105	.042	.080
Appearance second bench	.158	.379*	.275	.433**	-.013
Plant weight first bench	.159	-.011	-.028	.122	-.011
Plant weight second bench	-.020	.044	-.100	.062	-.040
Appearance flats inside	.238	.108	.062	.093	.027
Leaf rolling flats inside	.173	-.012	.001	-.070	-.048
Appearance flats outside	.427**	.193	.256	.232	-.221
Leaf rolling flats outside	.167	.081	.040	.037	-.114
Plant survival flats outside	-.153	-.084	-.255	.038	-.180

**Significant at the one per cent level.
*Significant at the five per cent level.

Significant correlations were obtained between appearance in the second bench planting and in the field in 1958. Highly significant correlations were found for appearance in the second bench planting and leaf rolling in the field in 1958, and for appearance in the field in 1957 and in the flats dried outside.

DISCUSSION

It is apparent from the data collected in these experiments that the environment in which the plants are grown very greatly affects their visible physiologic expression of a drouth stress. In every experiment from which data could be obtained, highly significant F values were obtained. The field plantings in 1957 and 1958 gave the highly significant correlations of .583 for appearance of drouth tolerance and .427 for leaf rolling. In the experiments conducted in flats, the highly significant correlations of .593 and .514 were found for appearance and leaf firing, respectively, when data from inside and outside the greenhouse were compared. A correlation of .293 was found between the first and second greenhouse bench experiments. Although there were several variables that could have contributed to the difference, no specific reason can be given for the nonsignificant correlation found between the first and second greenhouse bench plantings. Day length was held relatively constant between the two plantings but the use of artificial light may have affected light quality enough to bring about some changes in the plants. Light intensity was lower during the winter months, which could have increased the amount of chlorophyll in the plants. Shirley (15) found that in a number of species of plants, an increase in chlorophyll content occurred as the light intensity was reduced. A highly significant correlation was found by Chisholm (3) between chlorophyll content and drouth resistance in several varieties of barley.

The results obtained in the field and flats indicate that valid plant responses can quite often be measured for any given environmental complex if the plants are grown and tested under relatively similar conditions. Even though significant correlations were not obtained in the greenhouse bench, a positive relationship between the two experiments did exist.

It is obvious that many conditions in the field differ from those found in a greenhouse bench or in metal flats. There is no well-defined pattern of correlations between greenhouse bench and metal flat data and with that obtained in the field. Undoubtedly some of this variability is due to the environmental differences under which the experiments were conducted. All observations made in the first greenhouse bench experiment showed very low correlations with data obtained from the field. The appearance data from the second bench planting gave a significant correlation of .379 when compared with appearance, and a highly significant correlation of .433 when compared with leaf rolling in the field in 1958. The correlations of .158 and .275, which were obtained for appearance and leaf rolling in the second bench planting and in the field in 1957, overshadowed to a large degree the favorable correlations found in 1958.

The highly significant correlation of .427 found for appearance in flats outside and appearance in the field in 1957 was the only significant relationship found between the field results and those obtained from plants grown in flats. The author encountered considerable difficulty when using seedlings, since the small plant size masked any clear cut expression of differences in drouth reaction.

Leaf firing observations were taken in the field in 1957 and from the first greenhouse bench planting. A nonsignificant correlation of .200 was obtained from a comparison of these tests. Here again, no explanation can be given for the differences that produced the low correlation. The highly significant correlations of .402 and .656 found respectively for appearance and leaf firing in the field and in the first bench experiment indicated that the appearance ratings were materially influenced by the degree of firing. In the first greenhouse bench experiment, firing probably had the greatest influence on appearance rating that the plants received.

Although the correlations between appearance and plant weight showed negative significance in the greenhouse bench experiment, no differences were observed in the field that would lend support to these findings. It is possible that the bigger plants tended to have root systems sufficiently well developed to sustain them longer than the smaller lines. Two lines, 8 and 39, were exceptions to the pattern of small size and poor appearance ratings. Both lines had relatively small plants and still retained good appearance ratings.

Plant survival data that could be analyzed were obtained from only one experiment. Figures 2 and 3 show quite clearly that differential survival does take place. No significant correlations were obtained between survival and any of the other observed characteristics. Two lines, 21 and 24, did have very good survival, however. Line 21 had very good appearance in the flats as well as in the field and in the greenhouse bench experiments. Line 24 did not appear particularly good in any other respect.

If drouth resistance is associated with the ability to survive a given drouth stress, the very poor correlations between survival and the other characteristics tend to leave some doubt as to the value of the other observations. Enough data have not been accumulated to enable the author to conclude which is the most important and reliable feature to look for in a drouth resistant line. The extreme variability shown by the lines under different environmental conditions makes the author conclude that under conditions similar to those under which these experiments were conducted, it would be impossible to determine, conclusively, the most drouth tolerant line or lines.

SUMMARY

A series of experiments was conducted in 1957 and 1958 to determine if a simple greenhouse technique could be found for evaluating the inherent drouth resistance of inbred lines of corn. Plants from 40 inbred lines were subjected to drouth conditions in the field, in a greenhouse bench, and in metal flats. Data on appearance, leaf rolling, leaf firing, plant size, and recovery after a drouth stress were obtained from the experiments. These data were analyzed to determine what relationship there was between the various characteristics studied and how consistent they were under several environmental conditions.

Highly significant correlations were shown between all 1957 and 1958 field data with the exception that the 1957 leaf firing data did not correlate with any 1958 field data. The only correlations to show significance between the first and second greenhouse bench experiments were appearance in the first planting and plant weight in the second, and plant weight for the first and second plantings. Significant or highly significant correlations were found between appearance and leaf rolling in flats dried inside and outside the greenhouse. No correlation was found between survival and any of the other characteristics on which data were obtained.

Low correlations were found between characteristics observed in the field and those in the greenhouse bench and in metal flats. Appearance in the second bench planting correlated with appearance and leaf rolling in the field in 1958. Appearance in flats dried outside and in the field in 1957 also had a highly significant relationship.

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LINE NUMBERS, COMMON NAMES, AND PARENTAGE OF 40 INBRED LINES OF CORN ON WHICH DROUTH STUDIES WERE CONDUCTED

Line no.	Common name	Original parentage
1	ND 230	Minnesota No. 13 (Haney's)
2	53236	(SD 2 x SD 5) x SD2
		SD 2 - Selection from Wimples Yellow Dent
		SD 5 - Selection from the cross 1210 x B107
		1210 - Selection from Brookings 86
		B107 - Selection from Brookings 86
		Brookings 86 - Selection from Minnesota 13
3	53237	(SD 2 x SD 5) x SD 2
		Selection from the same cross as line 2
4	53238	(SD 2 x SD 5) x SD 2
		Selection from the same cross as line 2
5	SD 28	B2 x A158
		B2 - Direct selection from Reid Yellow Dent
		A158 - Unknown
6	53348	Selection from Rainbow Flint
7	B16	Yellow recovered 4 County 31
8	A73	G3 x AR9
		G3 - Unknown
		AR9 - Unknown
9	A277	A322 x R4
		A322 - See line number 10
		R4 - Selection from Funk Yellow Dent
10	A322	15-28 x 8-29
		15-28 - Selection from Rustler
		8-29 - Selection from Purdue Yellow Dent
11	A340	4-29 x 64
		4-29 - Selection from Silver King
		64 - Selection from Northwestern Dent
12	W2736	Second cycle line from the single cross 49 x 28
		49 - Parentage unknown; selection made in Minnesota
		28 - Unknown
13	W275A	(9 x H) x 714
		9 - Selection from Golden Glow
		H - Selection from Wig 25
		714 - Selection from a South American flint

Line no.	Common name	Original parentage
14	Oh45	W8 x Oh40B
		W8 - Second cycle selection from the cross W-M13 x M-A48
		W-M13 - Selection from Minnesota 13, it is synonymous with Minnesota A-11 and C11
		M-A48 - Selection from Northwestern Dent
		Oh40B - Selection from Lancaster
15	SD 24	B2 x A234
		B2 - See line number 5
		A234 - Selection from (C11 x C23) x $C23_2$
		C11 - Selection from Minnesota 13
		C23 - Selection from Reid Yellow Dent
16	54466	Selection from Rainbow Flint
17	7(W22)	(SD 7 x W22) x SD 7
		SD 7 - See line number 32
		W22 - Second cycle selection from 25 x B10
18	Oh43	W8 x Oh40B
		W8 - See line number 14
		Oh40B - See line number 14
19	B8	Selection from 4 County 63 x Golden King
20	A34	Selection from Rustler
21	A188	4-29 x 64
		See line number 11
22	Oh51	Selection from Clarage
23	Oh56A	(Oh56 x Ind Wf9) x Oh56
		Oh56 - Selection from Clarage
		Ind Wf9 - Selection from Wilson Farm Reid
24	R53	(A375 x M13) 187-2
		A375 - Reid Yellow Dent
		187-2 - Selection from Krug
25	SD 1	Selection from Fulton Yellow Dent
26	SD 2	Selection from Wimples Yellow Dent
27	56259	(SD 2 x SD 5) x SD 2
		See line number 2
28	SD 4	Selection from Brookings 86 which is a selection from Minnesota 13
29	SD 5R	Red kernaled selection from SD 5
30	SD 5	Selection from the cross 1210 x B107
		See line number 2
31	SD 6	Selection from Alta
32	SD 7	Selection from Sundstrum Hybrid which was a variety cross
33	7(W22)	Different seed source than line 17; presumed to be the same genotype
34	SD 26	Selection from Minnesota 13

Line no.	Common name	Original parentage
35	SD 48	Selection from Fulton Yellow Dent x (1210 x Brookings 86)
		See line number 2
36	56305	Selection from Edmunds County Red
37	56354	B8 x ND 230
		B8 - See line 19
		ND 230 - See line number 1
38	W32	Second cycle selection from R3 x AR9
		R3 - Selection from Reid Yellow Dent
		AR9 - Unknown
39	56920	Selection from Armstrong
40	56935	Wf9 (Y) (KR) (SK)
		Wf9 - See line 23
		Y - Unknown
		KR - Selection from Krug
		SK - Selection from Silver King